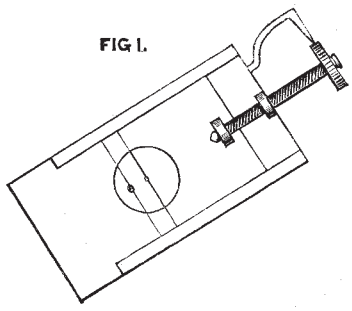
working they may be coupled up with the engine working the stern rudder, and all three rudders worked together. The dead wood has been cut away aft to a large extent in order to reduce the resistance to turning.

## DOUBLE STARS

SOME stars when looked at in a telescope are seen really to consist of two stars so near together that the naked eye is not able to distinguish them, but sees them as a single star.[1] The knowledge of some of these objects may be presumed to be almost as old as the telescope. In fact Hevel remarked some of them in the middle of the seventeenth century, but no attention was paid to them, as it was thought that they were really far asunder in space, and merely appeared close together in the heavens, because they were nearly in the same visual ray. It thus escaped notice that one star frequently moves round the other, and Lambert, as late as 1761, founded his opinion that those fixed stars that appear near others, were in no physical connection with them, upon this absence of relative motion, because, as he says in his "Cosmologische Briefe," if they do not move round each other, and still gravitate towards each other, they must long ago have collapsed. But a few years after the Rev. John Michell applied the rules of the calculation of probabilities to the stars in the Pleiades, and showed that it was exceedingly improbable that these stars could appear so near together, if their proximity was the result of a random scattering of the stars over the heavens, and he showed that among 40,000 stars, one could expect to find only one pair within twelve seconds of arc of each other, and none nearer. These speculations were, however wholly conjectural, as long as no proper observations were available, and it was therefore to the purpose when the highly merited Jesuit, Christian Mayer, of the observatory at Mannheim, founded by the Elector of Pfalz, commenced to search for, and systematically to observe, double stars. But he met with no support from his contemporaries, and had to defend his opinions in several polemical pamphlets. His instrument, a mural quadrant by Bird, was scarcely sufficient for the purpose, and his opinion, that, "satellites" of the brighter fixed stars were found at a distance of as much as three degrees, was certainly wrong in the instances he adduced, though Mädler has shown that stars as far asunder may possibly be physically connected.[2] We must, therefore, consider William Herschel to be the first who proved the existence of double stars. This he did by aid of micrometric measures,[3] which he originally had made with the view of finding the parallax of fixed stars, similar observations having previously been attempted by the Rev. Roger Long, of Pembroke College, Cambridge, who, however, had not been very successful.

Herschel commenced micrometric measures in 1776, when he observed $\theta$ Orionis. In 1779 he began systematically to search for and measure double stars, and as early as 1782 he laid his first "Catalogue of Double Stars" before the Royal Society. It contained 269 objects, but few of which had been observed by Chr. Mayer. Subsequently he published other catalogues, which, however, contain many stars more than 32″ asunder, which are not now considered as double stars proper; but of the latter Herschel discovered between four and five hundred. He measured double stars micrometrically up to 1785, and again for some years after 1790. The measures showed some discrepancies, but it was impossible to decide whether the relative motion of the components—for changed their position some of them evidently had—was rectilinear or otherwise, and whether it in some cases perhaps arose from the proper motion of one star. However, already in 1794 Herschel explained how they must move in curved paths on account of their mutual gravitation, and in 1803 appeared that famous "account of the changes that have happened during the last twenty-five years in the relative situation of double stars," in which he, from actual measures, proved this to be a fact. But Continental astronomers were nevertheless slow to give in to so




novel and startling a revelation. In France even Lalande openly expressed his want of faith in these disclosures, notwithstanding his high regard for Herschel's merits in other respects.—At the end of his active career Herschel had the pleasure to see his son John Herschel take up this subject with fervour. South, the friend of this illustrious astronomer, joined him in this work, and obtained thus a place in the scientific world, to which his own merits, only for this connection would scarcely have entitled him. J. Herschel went in 1834 to the Cape of Good Hope, where he discovered and made some measures of above two thousand double stars on the southern sky with his 20-feet reflecting telescope. He continued to take an active interest in these stars till his death in 1871, when he left behind unfinished manuscripts that showed that he had been engaged on a general catalogue of double stars and the observations made of them. It contained about 10,000 entries.

Meantime Struve in Russia had commenced a series of double-star measures, which is even now unsurpassed, as well with regard to extent as to consistency. In 1824 he received a 10-inch refractor, mounted equatorially, from Fraunhofer of Munich, and with this magnificent instru-

[1] Mizar and Alcor, the "test-star," in the great bear, present to the naked eye very much the same appearance as a double star does, when seen in a telescope. Their distance is about a lunar radius. It is sometimes said that distances less than five minutes are not visible to the eye, but when wearing glasses I see $\epsilon$ Lyræ, the distance of whose components is less than four minutes, double.

[2] It was evidently Chr. Mayer's opinion that the smaller star shone in reflected light. The term "double star" had been applied by previous observers, who little dreamt that these stars would become so interesting.

[3] It may be as well to explain in a few words the instrument with which such minute quantities are measured. It is called a micrometer, and forms the eyepiece of a large telescope. It is well known that in the focus of the object-glass of a telescope, the image of the object contemplated appears inverted. Now in this focus are stretched two parallel spider lines, at least one of which is moveable by an extremely fine screw. The magnitude of the object or the distance between the two components of the double star are thus measured in revolutions or fractions of a revolution of this screw; for which purpose the head of the screw is divided into hundredths, the tenths of which are estimated by the eye (see Fig. 1). The value in seconds of arc of each revolution of the screw is either ascertained by measuring some known distance or by measuring the length of a revolution in parts of an inch (a very small quantity) and dividing this by the focal length of the object-glass expressed in inches. The value of a revolution is generally found to vary a little with the temperature, as the steel of which the screw is made expands or contracts with the heat, but this is counteracted by changes in the focal length of the object-glass. It is of more importance to examine the irregularities of the screw, the different turns of which might not exactly be of the same size. Even parts of each turn might be slightly different. However modern engineers have carried the making of screws on the lathe to so high a perfection, that there are screws made in which no errors can with certainty be ascertained. It also deserves to be remarked that it is more easy to make a screw accurate the finer it is.—But the screw gives us only the distance of one star from the other. We require to know also in what direction it is situated. For this purpose the plate on which the micrometric screw and the wires are fixed can be revolved, and the wires placed parallel to the line joining the centres of the two stars. The angle is read off on a circle in firm connection with the tube. This, the so called angle of position is counted from the line connecting the principal star with the pole. From north 0° round through east 90°, south 180°, and west 270° (see Fig. 2). This circle is adjusted by allowing the stars in their daily motion to run from east to west along the wires. The index should then point to 90° or 270°. But it must be kept in view that the images are inverted, so that *e.g.* when looking southwards, north appears down.

ment he worked indefatigably for thirteen years, making above 10,000 measures ; and it may be said that by this telescope the genius of its maker carried the palm on behalf of refractors in measuring minute quantities in the sky, while the reflectors stepped into the background, and were subseqnently preferred only in cases where the definition is of less consequence than light-grasping power.[1] Struve not only made measures—thanks to Fraunhofer's excellent micrometer and his skill in handling it—more accurate than had been possible up to that time, but he also catalogued about 3000 double stars between the pole and fifteen degrees southern declination. He had their places exactly determined with Ertel's meridian-circle, and these observations, compared with those of later date, have in many cases established the fact that the proper motion was common for two stars, that revolved so slowly that no change in their relative position had been discovered by aid of the micrometer. Thus their physical connection is then established, but indeed "optical double stars" are so uncommon within the limits here considered, that the discovery of an optical couple is almost a greater curiosity. In such a case the micrometric measures serve to accurately fix the amount of the proper motion of one star, the other being generally so distant that it appears stationary, as well as to ascertain the parallax of the nearer star if perceptible. Struve also every night carefully noted the magnitude and colour of the stars he observed, and divided them into *Lucidæ* and *reliquæ*, according to whether the smallest star is above or below the eighth magnitude. According to their mutual distance, he divided them into eight classes, as follows:—

| | | | | | |
|---|---|---|---|---|---|
| Class I. | Distances from | 0″ to 1″ | Class V. | Distances from | 8″ to 12″ |
| ,, II. | ,, | 1 to 2 | ,, VI. | ,, | 12 to 16 |
| ,, III. | ,, | 2 to 4 | ,, VII. | ,, | 16 to 24 |
| ,, IV. | ,, | 4 to 8 | ,, VIII. | ,, | 24 to 32 |

Struve's principal works are : "Stellarum duplicium et multiplicium mensuræ micrometricæ per magnum Fraunhoferi tubum annis a 1824 ad 1837 in Specula Dorpatensi institutæ," and "Stellarum fixarum imprimis compositarum positiones mediæ deductæ ex observationibus meridianis a 1822 ad 1843 in Specula Dorpatensi institutis."

Though Struve achieved his main results after the arrival of Fraunhofer's refractor, he had made double-star observations as early as 1814, but his apparatus were then so deficient, that he had to try to make use of differences of right ascension observed with a small transit instrument, an attempt that, in spite of his experience as an observer, could not but prove a failure. His observations were subsequently continued, under his direction, by his son, who, with the 14½-inch refractor at Pulkowa, discovered about 500 additional objects. He has made about 7000 measures during the last forty years, and thus we are in possession of observations continued during about seventy years by the Struves, after the same methods.

Meantime, similar investigations had made considerable progress elsewhere. In England, the subject was taken up by the Rev. W. R. Dawes, who, taking into consideration the smallness of his means, achieved more than any contemporary observer. He is justly considered one of the most distinguished of those amateur astronomers, to whom British science is so much indebted. He made about 2000 measures in all. Subsequently, Baron Dembowski, in Italy, commenced micrometric observations of double stars, and though the means originally at his disposal would have been wholly inadequate in other hands, the accuracy of his measures was about as great as that attained at more richly-furnished observatories. Pushed on by his success, he acquired larger and better instruments from Fraunhofer's successor at Munich, and entered upon a series of observations, in which he greatly surpassed the accuracy of other observers. It is therefore to be regretted that the mass of observations he accumulated during a quarter of a century, has not yet been more than partly laid before the public. Investigators were, however, expecting a volume that would completely embody Dembowski's work, when the mournful news of his death in January, 1881, spread over Europe. Compared to his observations, those made by Sir W. Herschel appear to be as rude as observations made before the invention of the telescope, compared to those of the nineteenth century.

It was in the course of the researches carried on by the latter observers, that circumstances came to light which have proved to be of the utmost importance. I allude to the existence of systematic errors. Already Struve found that he measured angles of position differently, when he inclined his head to either side, and he found that in any case, his distances were different from those given by other observers. He did not, however, follow up this remark, but merely kept his head straight while observing, and with regard to the distances he did not see how his own results could deviate from the truth ; but his son, though he is in possession of such a great refractor, has been found to measure double stars altogether erroneously. This he has remedied by observing artificial double stars (white ivory disks on a black ground), and after applying the corrections thus ascertained to his measures on the sky, the accuracy of his results has been sensibly increased, though of course the circumstances attendant on such operations are very different from those under which astronomical observations are made during the night, *e.g.* the artificial double stars are always seen near the horizon and are stationary, while the stars are ever moving, and have to be followed by aid of a more or less deficient clockwork driving the telescope. Dawes also, found systematic errors in his measures. He tried to do away with them by slightly inclining his head when the stars were nearly in a vertical, and by the use of a prism, fixed before the eyepiece, to make them appear vertical, when the line joining their centres formed a great angle with the vertical. He says, in the introduction to his observations, that no one about to draw a straight line with a ruler would lay this crooked on the table ; one prefers to lay it parallel to the line joining the two eyes. It is in fact most agreeable to measure a double star when the components are either nearly vertical or nearly horizontal. Dembowski's observations seem free from systematic errors, but with praiseworthy diligence he has thought fit to subject this circumstance to a minute scrutiny. To this end he was observing circumpolar double stars of different classes in every hour angle round the pole, as these errors have been found to depend upon not only the angle the line joining the stars makes with the line joining the eyes of the observer, but also on their mutual distance, and as the error diminishes quickly as this increases, it is recommended to use always the highest magnifying power which the state of the atmosphere and the quality of the object-glass will allow.

Space would not allow me to refer to all the astronomers, who at one time or another have paid attention to the subject, or to discuss the relative value of their work. Father Secchi made some good measures in Italy, Duner, in Sweden, has published about 3000 valuable observations, and Gledhill, in Halifax, has also successfully taken up this work. In spite of the skies of Connaught, that clear so seldom and so irregularly, I have tried to do my best, but I have not succeeded in getting

[1] The definition of an image seen in a large reflector is inferior to that in a smaller refractor, both on account of the greater influence of any defect in grinding the surface of a mirror, and because, when the aperture is larger, the rays of light from the object have to pass through so much larger a portion of the atmosphere, the irregularities and motions in which render the image unsteady and badly defined.

more than 1000 observations up to this. Latterly, this branch of science has made distinct advances in America, where Burnham has made excellent use of the gigantic refractors, which are made by Alvan Clark of Boston. He has discovered a number of important double stars, the components of which cannot be separated at all in older telescopes.[1]

In 1878 the French astronomer Flammarion, who is so favourably known from his excellent popular treatises, published his "Catalogue des Étoiles doubles et multiples en Mouvement relatif certain, comprenant toutes les Observations faites sur chaque couple depuis sa découverte, et les résultats conclus de l'Étude des mouvements," a work that is highly valued by double-star investigators, but private observers will do well in consulting also Messrs. Crossley, Gledhill, and Wilson's "Handbook of double-Stars," with its "Supplement."

As remarked above Herschel found that changes had taken place in several systems of double-stars, and in 836 Struve was able to give a list of a hundred systems, where the components appeared to revolve; but on account of the difficulty of the measures, it was not easy to decide whether this was owing to actual motion of the star or in some cases to divergences of the observations. But he proved beyond dispute in about half the cases that the companion had revolved, and Mädler, who was one of the most indefatigable double-star observers, as well as the most prominent calculator, raised this number to several hundreds. His work, "Tabula generalis stellarum duplicium indicationem motus gyratorii exhibentium," was published in 1849, and contains 650 entries, but many of these were mere surmises, and have not been corroborated by subsequent research.

If the observations were absolutely free from errors, it would be an easy task to investigate the path of the companion, but in addition to the imperfection of every observed position, we have as explained above to guard against systematic differences between the different observers. In long series of observations of quickly revolving stars, this gives occasion to endless discussion. We draw, for instance, a powerful aid in discerning systematic errors, from Kepler's law, that the areas described by the radius vector are proportional to the intervals of time; but he would be a bold man, who in the present state of our knowledge, would affirm that all binary stars have been proved to revolve according to this law in elliptic orbits, in the focus of which the main star is situated,[2] or would condemn all observations that could not be made to fit into such an hypothesis. But though this assumption is a mere hypothesis, and may remain so for a long time to come, we have nothing else to guide us. In fact we cannot calculate an orbit at all except by aid of these laws.[3]

W. DOBERCK

(*To be continued.*)

[1] The difficulty of separating close double stars renders them fit tests for the performance of a telescope. Some idea of the quality of a telescope may be gained, when it is stated that it is able to separate objects of a certain class, be it *lucidæ* or *reliquæ*, but withal, it is preferable to try its performance on terrestrial test objects. A third sub-class "delicate" double stars, or those in which the companion is so minute compared to the main star, as to require a high degree of optical power to perceive it, has been added by Sir John Herschel, but it deserves to be remarked that the appearance of such objects depends quite as much upon the state of the atmosphere. The companion of Sirius, for instance, has been repeatedly seen in 4-inch refractors under exceptionally favourable circumstances, though in a great latitude. A large aperture is therefore not always an advantage. The situation of the observatory is of much greater importance. Piazzi Smyth has the merit of having for years insisted upon this point. The Lick Observatory, about to be founded on Mount Hamilton, California, will offer unusual advantages. Mr. Burnham has there already discovered some difficult double stars with a minor telescope.

[2] Both stars revolve, of course, round their common centre of gravity, but it is easy to see that the *relative* position of the two stars is all the same then as if only one revolved. If the changes in the absolute place of one of the stars were known, we would have the means of computing the relative masses; but this has only been possible in a few cases at most.

[3] In case of certain triple stars, whose movements do not fit into Keplerian ellipses, we have to represent the motions by aid of epicycles, just in the same way as Ptolemæus represented the motion of the planets in the system named after him.

## *THE MARIANNE NORTH GALLERY OF PAINTINGS OF "PLANTS AND THEIR HOMES," ROYAL GARDENS, KEW*

MANY readers of NATURE are doubtless aware that the large collection of beautiful and instructive pictures of flowers painted in various countries by Miss Marianne North, is now, through the noble generosity of this lady, the property of the nation. The collection is in a handsome building specially erected in Kew Gardens for the purpose, at Miss North's expense, and from designs given by Mr. James Ferguson, F.R.S. Last week the gallery was opened without any ceremony whatever, and henceforward it will be open and free to the public at the same times and hours as the museums and other buildings in the Gardens.

Now that this is an accomplished fact, a few words respecting the history and the principal features of the collection may be useful. Impelled by a love of nature, Miss North has spent many years travelling from country to country, and painting the most striking scenes and objects that came under her observation; and from time to time some of these paintings have been exhibited in London. The more Miss North travelled and painted, the more the desire to travel and paint seems to have grown; the result being a large collection of pictures. Then arose the question, what should be done with them? and happily in this Miss North was influenced by the kindly feeling that she would like other less fortunate persons to see and enjoy what she herself had seen and enjoyed so much. This idea once conceived, the warm-hearted artist and traveller set to work more assiduously than before, in order to carry it into effect, even visiting Australia and New Zealand, for the purpose of painting the vegetation of that region. In a country where the love of flowers is general from the poorest to the richest, such a gift as that now offered to the public will assuredly be fully appreciated.

The collection is designated in the title of the catalogue as paintings of "plants and their homes," and this title is justified by the fact, that in nearly all the pictures, plants have supplied the motive, the other objects represented being accessories. Altogether there are upwards of six hundred pictures, representing vegetation in nearly all temperate and tropical parts of the world except Europe and Africa, unless we regard Teneriffe as belonging to the latter country. A descriptive catalogue, compiled by the writer of this notice, and published at Miss North's expense, contains not only the titles of the pictures, but also short notes concerning the life-history, products, &c., of the plants painted, inserted with the intention of making it as instructive as possible to those who know least of such things. There are representations probably of not less than a thousand species, and these include members of nearly every natural order in the vegetable kingdom. The fruit and other useful plants of the different countries are numerous; and associated with them are many of the most ornamental and most striking wild and cultivated plants. In dealing with trees and shrubs, the artist has usually painted a flower-bearing or fruit-bearing branch, or both, in front, and given the habit of the tree or shrub in a landscape behind. Without being botanical, the paintings of the plants are so thoroughly naturalistic, that a botanist has little difficulty in determining such as are not known to him by sight. In so far as regards its prominent features and peculiar types, the Australian flora is more completely portrayed than any other, about seventy-five pictures being devoted to this region. Miss North visited Queensland, New South Wales, Victoria, Tasmania, South Australia, and West Australia; and from each of these colonies she brought home paintings of a large number of the most striking and characteristic plants. Thus of Eucalyptus there are portraits of *E.*